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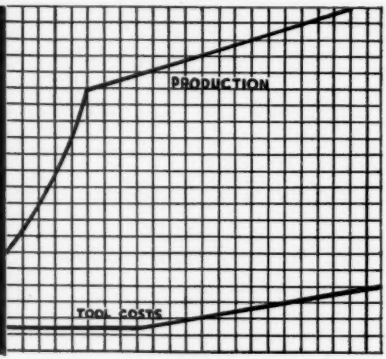

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PRODUCTION IN CASE OF NATIONAL EMERGENCY.

Paper presented to the Institution, Leicester, Southern, and Western Sections, and Loughborough College Student Centre, by A. C. Clinton, A.F.R.Ae.S., A.I.P.E.

Causes of an Emergency.

THE progress of machine production and communications during the last twenty years has changed the manner in which nations have developed and these factors have been exploited by zealous leaders in some countries. Europe is shared by many States, some of which are not able to manufacture the material for their defence, and this must cause anxiety to their governments. The tension in Western and Eastern countries is causing so much nervousness that watch is kept for any incidents that might be interpreted as a cause for war, for example: (a) insult to the flag; (b) unwise movements of troops or ships; (c) murder of a state official; these are the kind of things that might start your factories in a day and night race to produce the great amount of material that would be required by the nation.

Problems at the Outbreak of War.

Vast problems would face a nation at the beginning of a war, and suggestions for the preparation that should be made in advance to prevent hasty and unwise action will be given in these notes.

Finance, food, and material supplies as well as man power would be applied to national use by appropriate organisations, but production engineers would be particularly concerned with supplying the material needs of the fighting forces to whom the country looks for protection.

The question of the production of warlike stores after the outbreak of war is an immense subject, and the Government must rely on the goodwill of industry in the event of industrial mobilisation; industry being under no statutory obligation to give assistance.

Human nature, being resilient, would soon conform to new conditions and the quicker industry could adapt itself, the sooner would munitions be ready for use against the enemy.

Loughborough, October 13; Southampton, October 21; Leicester, January 22; Bristol, February 21, 1936. (*Vol. XVI, No. 2, February, 1937*).

The leaders of the country in deciding what should be the strength or size of a defence service are faced with six main considerations. These are : (1) The vulnerability of the country to be defended ; (2) the commitments necessary for the defence of overseas possessions ; (3) the protecton of sea communication ; (4) the force that it is estimated would be required to carry out strategic operations ; (5) the force necessary to ensure success of sea and land operations ; (6) the efficiency and strength of the air forces of prospective enemies.

Air Force.

Numbers alone would not be of prime importance, but high efficiency of personnel, armament, and equipment are essential, with a steady source of reserves, and sound organisation based on war requirements. Land and sea forces must be supported by an air force.

The striking force must be ready for immediate action on the outbreak of hostilities, and the entire air force must be of sufficient strength to gain and maintain air superiority. Behind this force the organisation must be such that losses could be made good quickly. This could only happen by husbanding and organising resources in skilled personnel, material, training, and production in peace time. Reliance must be placed on a flourishing civil aviation, which would provide the basis for expansion.

Civil aviation is growing slowly, but next to light and electricity, provides the quickest means of communication between nations. Civil aviation, however, developed as an off-shoot from the military department, and, as yet, is not sufficiently well established or large enough, to give much assistance to Air Force requirements ; it is essential at present for military aviation to have its own industry.

The Air Force is a technical service requiring complex equipment, demanding the highest grade of material, and the best manufacturing plant, which must be staffed with highly skilled personnel. Strength with lightness is essential for all aircraft work, and there is a constant demand from designers for improved steels, and light alloys, all of which must conform to an approved specification.

Progress in aeronautical science is rapid, and aircraft designs soon become obsolete. It has been usual for some time, often from two to five years, to elapse from the initiation of an actual design to the production of a proved aircraft. This situation is, however, being improved, and the finished machine should be ready in less than two years.

The nature of flying operations means a high percentage of wastage in war, and there have been many estimates of the figure. The losses of fighters would be expected to be much greater than that of heavy bombers, and supposing that the reserves allowed for four fighters

and two bombers, respectively for each fighter and bomber in the field, then some idea may be gained of what would be required to meet the demands in the early stages of a war ; the success of the Air Army would depend on the rapid expansion of the aircraft industry.

The manufacture of internal combustion engines is increasingly dependent on high grade material, in the form of forgings and stampings, and, if these parts were required in larger numbers at the same time as orders came flooding in from the other services, then it would be most difficult to fulfil the demands.

The Army.

A large proportion of the defence forces of this country consists of infantry, for which the main requirements are : mechanical transport, artillery, tanks, machine guns. Practically everywhere the internal combustion engine has replaced the horse for transport. The role of light artillery for supporting infantry attacks has changed since the last War, and now the tendency is for preliminary advances to be made by suitable tanks, designed to subdue the enemy and control areas ; following this operation, which largely replaces the artillery barrage of past battles, the infantry can be moved forward in lorries, or even on foot, supported by more tanks, and mechanical machine gun units.

Armament for the infantry would include guns of various sizes for use in light or heavy tanks, and in the artillery, also the machine gun. The new type recently adopted has yet to be produced in large quantities to serve existing needs.

There is much development work to be done in the design of tanks, which should combine speed and hitting power with efficient armour, as well as providing reasonable accommodation for the crew, who need space for rest, since they might be confined in their steel shell for long periods.

Tanks must maintain wireless contact during operations, especially in darkness, in fog or in artificial smoke screens, and there would be a considerable demand on the electrical industry for development and production work.

Owing to the small number of firms manufacturing armaments, the normal output of armoured fighting vehicles, as well as various types of arms and ammunition, is very limited, and would only cover a small percentage of the probable war wastage, which in the case of armoured vehicles might be as much as 20% per month.

It can be seen that the infantry is a technical service that would absorb a very large output from the munition factories.

The Navy.

The trend in naval design is towards ships of smaller tonnage having improved performance and better protection, especially from aircraft, while still retaining good hitting power. Design has been refined, and the best that science produces is used in solving new problems. Existing ships are rapidly becoming obsolete, earlier in fact than is indicated by the official dates, so that apart from the present building and repair programmes, it is to be expected that further ships will be laid down.

Owing to the use of more costly material, such as alloy steels, and light alloys, as well as the increase in equipment, warships have grown in cost from something like £80 per ton to £300 per ton during the last twenty years, but the source of supply of the raw materials must also serve the industries supplying the other services, especially the stringent demands of the Air Force. Obviously there would need to be a rationing of the material to the Services, in accordance with some plan that would enable the Navy, Army, and Air Force to expand on a co-lateral basis, since war operations depend on the co-operation of all the arms.

In addition to actual fighting, the Navy primarily, and then the Air Force, have important policing duties to perform, such as the preservation of trade routes, and the protection of narrow seas, so that if any order of priority in the delivery of raw material became necessary, the Senior Service would be first.

The auxiliary industries which provide material for the large variety of equipment demanded by the three Services cover a wide field, and are spread over a very large number of firms, so that an organisation to enable a steady supply of the right goods at the right time demands careful consideration.

The problem facing the three Services in general is the building up and holding of sufficient reserves to place a force in the sphere of operations, and to keep it equipped until war production is capable of meeting war wastage.

Since the Services will demand stores and equipment according to the various phases of the war, their success will depend on the ability of the industry to meet changes in supplies, and still keep delivery dates.

Industry then must be organised to cope with war wastage, while at the same time urgent demands are being made for stores of newer design.

In regard to replacing existing material, this would not present the same technical difficulties of design and manufacture as would new equipment, and such work could be spread over various factories leaving the parent works free to concentrate on the more difficult jobs entailing research and development, prior to manufacture.

The main phases through which a munition passes are: (1) Pure research; (2) applied research; (3) design; (4) production.

During peace much time is devoted to leisurely design, the result being that munitions tend to become complicated, so that a proportion of existing equipment would probably need re-designing on the outbreak of war.

If it were possible for industry to turn over almost immediately on outbreak of war to the production of the many complicated types of stores required, the money to be spent in peace time on war reserves could be reduced to a minimum. This ideal can never be attained, and, generally speaking, the adaptation of industry to the production of war stores, not normally produced in peace time would take from six to twelve months, according to the type of stores, and that only if this transition has been most carefully planned, and if specifications, jigs, gauges, and such like, are all available to meet production demands.

Where tools, gauges, material, are not available the time for production may be doubled.

Industrial Resources.

The main resources possessed by any country consist of: (1) The mental and manual power of the people; (2) land and mineral deposits; (3) the material capital of buildings, plant, railways, ships, and stores of goods; (4) the immaterial capital of organisation.

These resources are in operation in normal times, producing a steady output in goods and money. Conditions may not be stationary, since owing to changing demand, money may be diverted from one industry to another, but whether conditions are stationary or progressive, the country's resources would not be worked at the maximum intensity, and, therefore, the maximum dividend would not be obtained; partly because people want leisure as well as goods, and partly because change in demand usually involves alteration to organisation and plant.

In case of war, all useful resources would be organised for national output, and the maximum production demanded.

Man is the most important of war factors, and he is wanted both in the various branches of the defence services, and in the various departments of the industrial army which maintains the defence forces.

The kind of man, and his value for technical labour, is the concern of all of us. From experience it has been found that it is fairly easy to turn out rapidly half trained machine minders, able to manufacture material, or manual workers able to make chemical products. and explosives. These workers depend for their training, supervision, and output, upon a skeleton staff of trained and experienced

engineers. It is necessary, then, that industries essential for war should maintain a sufficient number of staff for technical and organisation duties.

The ramifications of the war industry are vast in numbers and proportions, and some of the most important industries that concern the majority of production engineers are : (1) Food, including sugar, fat, flour ; (2) fuel, including coal, oil ; (3) ore, including ferrous and non-ferrous ; (4) textile, including cotton, wool ; (5) chemical, including fertilisers, mineral salts ; (6) water power.

It has been mentioned that unskilled labour can be trained to mind machines and that the instruction is not a difficult matter for experienced engineers, but it would become a hard task if the available industrial recruits were expected to work twelve hours on inadequate food rations ; the lack of suitable food caused much real hardship in the last war, and this country is still dependent on continuous supplies from across the seas, amounting to approximately 20,000,000 tons per annum.

As the surface of the earth feeds man, so the lower strata feed industry, coal, various ores, salts of all kinds, mineral oils, and so on. These things are at the base of the iron, steel, and chemical trades. Most important, after man power, are materials, and the country which can command resources of raw materials holds a strong position. As much as 27,000,000 tons of raw material are imported annually into this country.

Basic industries must be on coal fields, and a glance at the map of Europe shows that a line passing approximately through Stockholm, Danzig, Cracow, Budapest, Florence, Barcelona, Bilbao, around France and England, and through Glasgow, joining up with Bergen and Stockholm gives a comparatively small area containing all the large and important industries, as follows : (1) Coal mines ; (2) metallurgical industries ; (3) chemical industries ; (4) factories for electrical material, engine material ; (5) naval dockyards.

It has been mentioned that the resources of peace time may change according to demand, and progress, and to this extent the war time resources also are changed.

The substitution of certain raw materials for some uses by synthetic products is an industrial resource of great value, a few of such developments are : (1) Extraction of nitrogen from the air ; (2) artificial fertilisers ; (3) liquid fuel from coal ; (4) use of plastics in place of wood, metal, pottery, and stone ; (5) food from wood ; (6) synthetic rubber.

The industrial capacity of a country to extract the maximum value from its resources, depends on : (1) The personnel ; (2) machinery and plant ; (3) nature, age, and technical value of the

machinery and plant; (4) rapidity with which resources can be brought into action.

Likewise the productive capacity of any particular industry depends upon these four factors.

Within this country, the industrial areas, with the exception of London, are centred round coalfields.

These areas are :—

(1) The Clyde, Forth Valley, and neighbouring Ayr coalfield. Iron ore is obtained in Lanark and Ayr. Associated with the Ayr coalfield are the shipbuilding works of the Clyde, and the industries of Glasgow, Coatbridge, Kilmarnock, Paisley, and Dundee.

(2) The Northumberland and Durham coalfield, with the associated Cleveland iron ore fields, has the shipbuilding yards of the Tyne, and the engineering works of Newcastle.

(3) The Cumberland coalfield is of less importance, but supports the shipbuilding at Barrow, and iron works at Workington.

(4) The most densely populated area of Great Britain outside London is that around the Lancashire coalfield, where the production of cotton manufactured goods takes place. Associated with this area is Liverpool, Manchester, Wigan, and the cotton spinning and weaving towns. Just to the South of this area is the North Staffordshire coalfield, which makes an almost continuous belt of densely populated country, northwards from Stafford to Preston, which supports the pottery centres.

(5) There is the York, Derby, and Nottingham coalfield, which with the Midlands coalfields, in Leicester and Warwickshire, form a long belt of dense population, from Leeds to Burton-on-Trent, and Leicester. Industries in this area incude steel, iron, motor cars, bicycles, leather, and woollens.

(6) The South Staffordshire coalfield, which also produces a considerable quantity of iron, supports the engineering industries around Wolverhampton and Birmingham.

(7) The South Wales coalfield supports the metal smelting industries round Swansea and Newport. Associated with this area is the smaller Bristol coalfield, and the industries concerned with tobacco, cocoa, sugar refining, aircraft, and general engineering. The Port of Bristol would become most valuable in the event of any threats to the Eastern side of the country, though communication to the East by road and rail is limited.

(8) The last area of dense population is London, so well placed for communication with the ports and commercial centres of Western Europe.

Besides men, and the directly productive plant of the essential industries, there is the indirectly productive machinery such as the

organisation of production to be mentioned later, and the system of transport within and without the country.

Under transport important points are : (1) The layout of the railway system, the nature of the rolling stock, and the power of the locomotives ; (2) the network of main roads, and the kind of lorries available ; (3) the inland waterways, and the barges that could be used ; (4) the air transport system, and the location of civil aerodromes.

Transport Within the Country.

Railways would be faced by a most difficult task in meeting the demand for continuous goods services in addition to passenger services, and communication with Wales will be greatly improved when the Severn Bridge is built.

A brief glance at our transport system shows that to make it more efficient a road system needs to be energetically developed, so that high speed vehicles can connect all parts of the country. Especially is this important for communication between the West of England ports and the Eastern areas. Even in the last War, the unusual loads of food could not be cleared from Avonmouth sufficiently quickly to prevent wastage.

The canal system is capable of further development, though it is not possible to speed up the motor barges owing to damage to the banks.

Air transport is developing, but cannot be classed with rail or road systems in general usefulness for load carrying or day and night operation in bad weather.

While the main burden of distribution would fall on the railways, motors would give a good secondary service on all main roads, and would be the main distributing service for scattered towns and villages.

Transport Without the Country.

The Mercantile Marine, protected by the Navy, is the lifeline, and without it transport within the country would be idle. Shipping continues in all weathers day and night.

Marine aircraft can assist in the protection of shipping, and in patrolling narrow seas or limited areas of open sea, but this work is dependent on weather conditions.

For the protection of cargo boats, there is nothing better than the proved principle of convoy, and it is the duty of the Navy to give protection, assisted when possible by aircraft. Since convoy speeds vary from seven to 12 knots, escorting aircraft would have a difficult task in keeping a close warch, and it is thought that autogiros would be helpful (weather permitting), especially as they could be carried on some of the vessels, and used as required. The

speed of the autogiro would enable it to circle the convoy, and keep a careful look-out, which would be of great assistance to the escorting naval vessels. Further, it would assist in controlling the station keeping of all the ships.

Organisation for War Production.

There are three main methods: (1) Active war industry; (2) reserve industry; (3) reserve stocks.

(1) The active war industry consists of naval dockyards, arsenals, explosives factories, aircraft factories, and so on, in which the State makes its requirements for the Navy, Army, and Air Force; the material being produced under the direction of engineer officers, and a permanent staff of civil assistants. These Government establishments, besides carrying out development work during peace, also build up a reserve of material according to some schedule.

(2) The reserve industry consists of all the private establishments of the same kind which, in time of peace, manufacture industrial goods and products, or also manufacture naval or military material for the State. These establishments, on outbreak of war, devote themselves exclusively to the manufacture of war material with their own machinery, or machinery provided by the State.

(3) The reserve stocks consist of holding supplies, which are often perishable and soon out of date, of keeping models on hand, and having factories ready supplied with machinery and raw materials, which would be ready at a moment's notice to manufacture up-to-date munitions.

These methods have advantages and disadvantages when considered singly, but by a combination of them, a considerable degree of preparedness might be attained, and this might reduce the time of transition from peace to war production.

An organisation similar to the Ministry of Munitions of the last war would be necessary to plan the work and output of the three methods, and it would come under the control of a Defence Minister.

The work of co-ordinating the resources of the three Services at the present time is done by the Minister for Co-ordination. This man is responsible to the Prime Minister, who presides over the Committee of Imperial Defence, which Committee includes representatives of the three Services, and two sub-committees:—

(1) The Chief of Staffs, whose duty it is to advise on the defence policy.

(2) The Principal Supply Officers, whose duty it is to advise on the production of war material for the Services, in other words, to plan the industrial mobilisation of the country's resources.

A large number of sub-committees exist dealing with various aspects of the preparation for war, and with the maintenance

of the Services, these committees being responsible to their own Departments, and finally to the Committee of Imperial Defence.

A Minister of Defence should control the three Services and their supplies. Supplies would be the responsibility of the Ministry of Munitions, who would not be expected to deal with matters of strategy.

A technical service such as the Air Force has its requirements administered and organised through a technical department of the Air Ministry, and the supporting aircraft industry has a trade association, the Society of British Aircraft Constructors, which maintains a liaison with the Service requirements, and Government Experimental Establishments.

The Air Ministry controls research and experiment, and this work is handled in detail by various committees which report to the Aeronautical Research Committee, and this body consults with the aircraft industry in regard to new developments.

This is briefly the technical organisation which handles most of the problems of the aircraft industry.

Emergency production organisation is being developed by the Government Supply Boards, in conjunction with the industry, and it has been found that the following points need attention :—

(1) Simplification of design.

(2) Standardisation of material and auxiliary equipment.

(3) Quick method of testing finished products.

These matters vitally affecting production are being studied, but the fact that it is necessary for the threat of an emergency to occur in order to focus attention on production can be explained by the fact that the aircraft industry is small, and being young, is full of enthusiasts whose one aim is to improve the breed, and every effort naturally is made in that direction.

Progress in the art of aeronautics, then, is jointly the result of efforts by the Government research departments, and of the research staffs of private firms, and this work is most fruitful. There is work, however, in addition to the technical research and mass production organisations for an official to act as an engineer-planner of the aircraft industry who might be a senior official of the Supply Board. The work of this man would concern every phase of organisation for production, so that designers, experimental engineers, and their staffs, would be free to spend their time in the most efficient way, without having to search for labour, for material suppliers having suitable stamp shops, or for efficient sub-contractors.

An important function of this engineer-planner would be to anticipate the requirements of the future, and to do this he would need to be in close touch with the Defence Minister. The aircraft manufacturers might then be informed as to probable future

developments, so that a programme could be planned, and experimental work apportioned throughout the industry; tending to flatten peaks and raise depressions, at the same time providing a picture of the requirements in case of an emergency.

With similar arrangements for the other two Services, the Government would know accurately to what extent the armed forces were up-to-date; also by means of scientific planning a smaller proportion of obsolete equipment would be clogging the three Services.

In regard to the continuity of technical work in the Navy, Army, and Air Force, the Navy already has a well-established engineer division, but the Army, which is rapidly becoming a technical service, needs to extend its engineer corps; while the Air Force, which is still young, must build up a strong engineer division for the efficient handling of the many technical problems.

Industries in Peace and War.

Various estimates of the time required to transform industries have been given, ranging from four to twelve months. Manufacturers dependent on the heavy industries would probably take twelve months to start delivering the vast quantities of material required. Therefore, more than twelve months would elapse before certain munitions could be supplied in large quantities to the Services. During the last war, at a period when production was most efficient, the time of delivery of guns was six to nine months, and that of shells six months. Though in special cases, deliveries could be speeded up, it would be at the expense of delaying other kinds of armament.

The possession of great natural resources, of industrial plant, and ample money, does not necessarily enable a country to change quickly from peace industry to war industry: the chief example of this being the United States of America, which at the close of the last war was still dependent on the Allies supplying her Army with large quantities of munitions.

Civilisation has advanced a great deal in the last decade; machine production, transport, communications, while being developed to the utmost for civil application, are not widely used in the defence services, although a start is now being made, and it is desired to emphasise what an arduous and long task is involved in re-equipping the Navy, Army, and Air Force with sufficient and up-to-date material.

The present expansion of industry which is keeping shops busy, should be considered as a rehearsal for an emergency, and the information gained should be subjected to careful examination, so that improvements in organisation and methods may be made, which will tend to establish confidence, so that an emergency could be faced with comparative calm.

There are several points that concern the production of the munition, a few of these being : (1) Planning the forward programme ; (2) raw material planning ; (3) machine equipment ; (4) jigs, tools, and gauges ; (5) simplification and standardisation ; (6) inspection ; (7) labour ; (8) sub-contracting.

(1) Planning the Forward Programme.

According to the type of munition and its state of development, forward plans might fall into three main divisions : (a) Periods up to six months for items such as clothing, chemicals, light machinery, light armament, ammunition ; (b) annually, for items such as mechanical transport, shells, aircraft ; (c) two years and upwards, for heavy guns and ships.

Government plans for emergency production, once made would be available, and maintained up to date by periodical revision and test, and, on outbreak of war, it would be known what work could be put in hand at a given instruction. In conjunction with the state scheme, firms would need to have their own plans for starting work with a minimum of delay, and this would mean that selected factories would necessarily be responsible to the Government for the plans.

(2) Raw Material Planning.

From the previous item the information would enable estimates to be made which would indicate the kind and amount of material required, and hence the cost could be determined for the different sections of the plan. Market prices in war time would be subject to control as the supply of material would be rationed in accordance with the demand for the munition.

The supply of raw material and the earliest delivery dates of munitions are most important factors, and, generally quick output would be demanded with little regard to cost, but sooner or later, if the supply of some material were threatened by blockade, or other reason, sudden efforts would be directed towards the recovery of waste materials. It is difficult to realise that the regular deliveries of raw materials might one day cease to arrive at the inwards stores, and precautions should be taken for the economy of supplies. It is suggested that in any planning scheme, provision should be made for the study of waste material, and its uses, and, that periodically the research department responsible should report on the saving that could be effected.

(3) Machine Equipment.

While it would be an interesting task to scheme out the production shop programme of processing and operations, it is a difficult problem to obtain sufficient machine tools to meet fully the pro-

duction programme during the first six to nine months; and this period might be longer in cases where special machine tools had to be designed for more efficient output.

As the designer must use careful judgment in the creation of his work, so must the production engineer in the arrangements for manufacturing that work. Consideration must be given to: (a) general purpose machines with and without special attachments, and (b) special purpose machines.

The degree of standardisation of machine tools obviously depends on the length and intensity of the production programme. Whatever machine tools might be required, they should be adapted in the best way for the work, safeguarding, lighting, seating, accessibility of controls, and the other features, desired by the shop manager.

Machine shops being liable to change in layout, means that portability should be an essential feature of machine tools, and it should be possible for these to have provision for the fitting of temporary wheels, and so make the task of the maintenance engineer a little easier.

When the present expansion fades there will be some machine tools left which will not be in a fit condition to start a heavy production programme should an emergency arise. It must be realised that replacement machine tools and spare parts will be required in order to put the emergency plant in efficient order. This fact means that in two or three years the cost of some of the equipment must be written off.

The supply of machine tools required for the present expansion could not all be obtained in England, and large numbers have been imported, without any serious difficulties, but this would probably not be the case in a war, even with the aid of neutral countries.

(4) Gauges, Jigs, and Tools.

These are essential at the outset of any production programme. The lack of these in the last war delayed the start of production in many industries, and is also affecting the present expansion. Owing to the skill required for making gauges, time was required in which to train suitable workers, and efforts were made to standardise components, so that the number of different sizes of gauges was reduced, an example of this being screw threads.

To meet the possible needs for a quick production there are two suggestions: (1) Keeping a supply of gauges, jigs, and tools in stock; (2) having plant and labour available for making these jigs and tools quickly.

Scheme (1) would mean keeping a large stock of valuable material, a proportion of which would never be used, since it would become obsolete, involving replacement by the latest material; under

scheme (2) it would also be necessary to keep sufficient material in stock against an emergency to cover the period taken for the plant to produce further sets, but the advantage of this scheme would be that the plant and workers would be up to date in machine tools, thoroughly experienced, and capable of immediately starting on any kind of gauge, jig, or tool required.

In the industry to-day, there are few firms which are capable of producing the type of gauges for measuring the accuracy of parts such as are required in torpedoes, aero-engines, optical instruments, and fuse caps. Existing gauge-making factories are finding it difficult to deal with the increased demand for gauges and jigs, and it is certain that in case of suddenly increased orders that there would be a long delay before deliveries could be made.

(5) Simplification and Standardisation.

By the time a munition has passed through the research and development stages, it may have lost some complex parts, and unnecessary adornments, but usually there would be scope for the production engineer to put it through a simplification process, having in view such things as : (1) Reduction in different kinds of raw material ; (2) reduction in number of parts ; (3) simpler manufacturing operations and inspection ; (4) easier training of labour ; (5) reduction in overheads.

In addition to the chief firms who supply the finished munition of various kinds, there are a large number of subsidiary trades supplying those firms with commodities. These subsidiary firms actually supply material to a variety of the finishing industries, and if it is possible for one of these suppliers to adopt mass production methods, it may be able to reduce the price of its product, provided other finishing industries will use a standardised article.

The standard of quality and output of subsidiary firms must fall in line with that of the finishing firms, and mass production methods in industry have benefited a large group of trades, for example, mass production in the motor industry has led to mass production in the foundry and spring trades, it has increased invention and improved manufacturing processes.

How far standardisation should be pursued in industry is a controversial matter, and it is thought that the degree of standardisation economically possible depends partly on the demands of the consumer.

A plant with unspecialised machinery and processes, and with a wide range of products, adapts itself gradually to movements in demand, while a firm specialising in standard goods can alter its production to meet changes only by a violent alteration of its processes.

Mass production methods are satisfactory if the demand is stable

over a long period or if the quantities of goods required are sufficiently large to cover the cost of intensive work over a short period; in a war industry the second condition holds good, and mass production and standard methods must be exploited to the utmost.

Standardisation would then affect a large number of subsidiary trades, and production engineers in these trades should scheme out how their plant could be expanded for largely increased production, without the necessity of closing down during the period of reorganisation.

Standardisation, while it may assist the production engineer, is not always looked upon favourably by the designer who desires to use the latest discovery of science, and the newest alloys, but in the early stages of emergency production, it would not be possible to make the very latest design of munition in large numbers; therefore reliance would be placed on a proved model, and a smaller number of the new types would be made for use, as a special reserve, until such time as production of these could be undertaken with success.

(6) Inspection.

One of the problems of the expansion is that of maintaining the quality of the product, and it applies to most of the equipment and stores for all the defence forces. Quality control is of great importance since very large numbers of conponents for items such as guns, aero engines, aircraft, scientific instruments, must be accurately produced; and while efforts may be made to simplify design and standardise materials there can be no "let up" on inspection.

An inspection department is an expensive overhead and in quieter times has probably been kept small, being run with the minimum of expenditure on equipment and personnel. For efficient inspection it is necessary to employ men who know something of the work, they should be skilled in the manufacture of the kind of article that they are to inspect, and it is an advantage that they should be of mature age with a good practical experience. Such men should form the foundation of the inspection department, but in a rapidly expanding concern these men would be scarce, since they might be required in the shops, therefore, new men must be trained with the greatest care in inspection methods and procedure.

Female labour can be trained successfully to do useful routine inspection of components, and it is thought that there are still many works where a nucleus of women might be trained with a view to becoming supervisors, should rapid expansion be required.

There are also many women well suited for routine testing and inspection work in the laboratory.

It should be remembered that a workshop cannot be considered as properly tooled up until it is provided with inspection equipment,

as well as production equipment, and it might happen that the completion of the inspection equipment would take a long time if it had to be designed and manufactured for the checking of some special parts.

It is difficult to maintain 100% inspection in a factory where different qualities of product are made, since there cannot be two standards for an inspector. Different products should be dealt with in separate inspection departments.

A salvage section connected with the inspection department is useful as a clearing house for doubtful parts, but the decision as to what items may be passed should be given by the department responsible for the design.

(7) Labour.

Experience of the last war showed that our opponents yielded only when weakness was caused through shortage of food and material, due to the blockade, and when the people were shaken by the superiority of man power and armament. Published histories of the three Services during the period of 1914 to 1919, though containing accounts of gallant and clever work, do not indicate that there was much to be done in the war, except to continue the long process of wearing down the opposing forces; the means of carrying on this action was supplied by the munition workers throughout the land, and the work was organised and brought to fruition by the production engineers in many industries.

In varying degrees most engineering trades are to-day eagerly searching for skilled workers; there are not enough for present needs, so that recourse to intensive training would be necessary in an attempt to fill the gap made by the derth of trained lads since 1919. If we are to prepare even for a modest increase in trade, more skilled men will be required, and anything demanding greater preparation means a national organisation of labour resources.

It is interesting to note that the facilities for the technical training of youth are increasing, and in a few years these sources will yield useful men, but we are still faced with the immediate problem of finding sufficient skilled labour.

Juvenile labour, though not of great importance, is useful, but will be less readily obtained when the school leaving age is raised.

Since warfare becomes increasingly a conflict of mechanised material, so the proportion of engineers and administrators will grow, for the organisation of the mobilised industry.

Large numbers of workers are not necessarily an asset unless they possess some aptitude for their tasks; this was apparent during the last war, when France employed coloured labour, which could not be trained for simple repetition work.

The character, intelligence, and morale of the workers are most

valuable assets, and from experience it is apparent that nations in the more northern and colder countries produce the best in engineering progress.

Having the right workers, and the means of training others, it is essential that some scheme of recruitment and training should be started that would ensure a reserve.

Production engineers are in a position to visualise the vast strides in engineering progress that have been made in Russia, and, though the first Five Year Plan was not entirely successful, it resulted in the Second Five Year Plan, which has progressed reasonably well, especially in regard to the labour question. The result is an example of what can be achieved by organisation.

In the event of war, would production and distribution be carried on according to the industrialist and capitalist method, as at present, workers being paid normal rates of wages, and the contractors taking their profits, or would everything be organised on a military system, that would enroll every industry and every economic activity ? It is interesting to speculate on the production that would be obtained by the two methods.

Would a militaristic system applied to an old-established industrial country like Britain have much chance of success, without first of all destroying numerous self-contained industries, many of which supply the large mass production finishing factories ? For example, there are trades in the West Midlands which design and make their own plant in order to manufacture their product ; the men in charge of such works must frequently have a far wider engineering knowledge than some who may be controlling specialised departments of much larger concerns, and a sudden change in organisation might leave serious gaps in the output of commodities for munitions, as well as causing dissatisfaction (especially when a process is dependent on the particular traditional skill of craftsmen).

Any change would need to be planned carefully, and the new scheme allowed to unfold—as it is by evolution rather than revolution that the most efficient results will be obtained.

Since dilution labour would be required in practically every industry, a census of labour available, and that required for war production, would be a useful step in conjunction with the planning of works and material supplies. It would be a step that would help to smooth any national mobilisation, and it would soften the hardness of conscription, which British temperament dislikes.

It would be doubtful if many industries would be able to work double shifts, at any rate at the beginning of a war. The scheme of working three eight-hour shifts is desired by some shops, but, again, it would not be likely that the number of suitable workers could be found to provide these shifts, and further the question of supervision would raise problems. The housing of workers would

arise in some areas, but this is a question always likely to confront the management of a progressive industry.

Enemy propaganda prior to any war, and during its early and difficult stages would undermine a proportion of the workers, reducing their value.

In the endeavour to secure superiority in the early stages of a war, attacks would be made on our factories, and such attacks, or the anticipation of such attacks, more especially at night, would mean decreased output. It has been found from experience, that when the conditions are favourable for air raids, 50% to 75% of the workers may not attend work, whether the raid actually takes place or not. Non-attendance at work occurs in districts remote from the known danger areas, and the moral effect is likely to be far reaching.

Practically all industrial areas would suffer in varying degrees from the effects of air raids, and although the physical effects might not be as intense as some writers would have us believe, the mental effect on the workers would be great, and this factor would need a large contingency allowance in drafting out any production programme.

In 1916 there were thirteen different weeks in which the Cleveland area was flown over by hostile aircraft, and usually there were only a few machines ; a considerable reduction in output resulted ; which was estimated at one-sixth of the average annual output ; the general effect on other areas touched by air raids was similar.

To combat the demoralising effect of raids mental control is essential ; the workers must have confidence in their managers and know that every reasonable precaution had been taken to meet air raid conditions ; these will be mentioned later.

(8) Sub-Contracting.

Manufacturers receiving larger orders than they could handle quickly with existing facilities would sub-contract to firms able to do the work, and give deliveries to meet the plan. Manufacturers with large orders might sub-contract work in order to leave a part of their facilities free for experimental and development work, and specialist firms would certainly need to keep a proportion of their shops available for development work and, therefore, would require sub-contract facilities.

The principle of de-centralising manufacture helps to lessen the danger due to air raid damage, and also labour trouble which might cause the hold-up of output if all components were made in one place.

For sub-contracting to have every chance of success, there must be close co-operation between the parent firm and the manufacturing firms.

The article to be manufactured must be a proved and practical proposition and once the specifications and drawings have been issued, there should be no modifications for a stipulated batch, so that the chance of delays may be minimised.

The parent firm should have a detailed procedure covering instructions relating to material, inspection, labour, manufacture, operations, processes, jigs and tools, packing, etc. The kind of things to be included are :—

(1) Material specifications giving chemical analyses mechanical tests, with instructions for the selection and test of samples.

(2) Shop capacity, machine tools, heat processes, chemical processes.

(3) Method of manufacture of raw material, e.g., forgings, castings, bars, and particulars of heat treatment.

(4) Details of processes during manufacture of components, e.g., nitriding, plating, etching, magna-flux inspection.

(5) Manufacturing operations—operations for each component.

(6) Inspection instructions. Establishment and maintenance of a model room, and standards room.

(7) Method of testing sub-assemblies and/or the completed article.

Even when a procedure as outlined exists it would be necessary to revise it carefully before its issue to sub-contractors : the manufacturing procedure could be amplified by lectures, sound films, and demonstrations.

The above few remarks indicate that the parent firm would require a sub-contract manager with a staff of engineers for instruction and supervision, and an office staff to handle correspondence and records.

Air Raid Precautions.

The production capacity of a nation depends on geographical situation, since the value of any industries located near a frontier must be discounted, as in a war they would be the objects of immediate attack by air.

In the case of this country, it is probable that most industrial areas would be visited by raiding aircraft which had their aerodromes anything up to 1,000 miles away.

For some centuries prior to the last war this country had been free from attacks by hostile forces, but twenty years ago a mere handful of slow flying aeroplanes presented the problems of how to protect the population, the public services, and industrial plants of all kinds. At that time air attacks did not penetrate far into the Western industrial areas, but where raids did take place, the results were serious, not perhaps so much in material damage as in mental disturbance. In many districts, over wide areas, the threat of an

air raid struck fear into the population, and the necessary precautions that were taken greatly reduced the efficiency of the nation's work.

The effect, then, of air raids is first of all mental, and then material. Precautions against raids must provide for the instruction and discipline of the population so that individuals may be better able to withstand anxiety due to the threat of raids, as well as to know what to do when raids take place.

With regard to the protection of material, average precautions should be taken. It is possible to make a building proof against bombs, but the result would be a fortress, and not a place which could be used efficiently as a dwelling or a factory.

The many problems concerning protection are being handled by the Air Raids Precaution Department, which is a branch of the Home Office. This department does not try to arrange the detailed organisation throughout the country, but acts in an advisory capacity to the local authorities, who, having a particular knowledge of their districts, are able to apply the principles in the best way.

Production engineers are concerned with maintaining their plant in efficient working order, and giving all reasonable protection to their workers.

Little protection can be given against direct hits by bombs, but the damage from the explosion can be lessened by means of splinter and blast proof walls, these walls being of bricks or sand-bags. Such precautions would be useful for the partitioning of large shops, for the protection of windows, entrances, and, the distribution control points for gas, water, and electricity.

In case of raid warning, the workpeople might be dispersed to their homes, or to shelters, but a certain number of men would be required to remain in the factory in protected posts to act as sentries, whose duties would be to cut off electricity, gas, and water supplies, and to deal with any small fires that might result from the raid.

Some of these look-out men would be responsible for removing certain jigs, and gauges, to underground stores, where there would be kept, also, similar equipment not actually in use, as well as drawings and specifications.

Since a raid may include the use of gas as well as high explosive and incendiary bombs, certain precautions must be taken to minimise the danger from contamination. Shelters and protected posts, must be proof against gas.

The general problem of protection against air raids is chiefly one of organisation, and if a carefully prepared plan is made to meet the danger and damage, that might be expected, something would be achieved in regard to giving people confidence.

Since those in charge of works would have the responsibility of mantaining output with as little stoppage as possible it is suggested

that an air raid precaution scheme should be prepared in outline as a guide to the amount and scope of the organisation required, which would include items as follows: (1) Warning system and lighting restrictions; (2) instruction of employees in regard to protection against gas and high explosives, ambulance arrangements; (3) shelters, which besides giving efficient protection must provide reasonable comfort, and be immune from flooding in case of any burst pipes; (4) protection of buildings, machinery, and plant; (5) fire arrangements; (6) gangs for building and repair; (7) maintenance of supplies and provision of spare parts; (8) alternative essential services.

This list indicates divisions of the organisation that would need handling by section leaders, and, as can be imagined, the work involved is considerable, and it must be well carried out so that in the event of an emergency the casualities might be a minimum.

In Conclusion.

The problem facing the defence forces is building up and holding sufficient reserves to place a force where required, and to keep it equipped until war production can meet wastage.

The industries supplying the needs of the forces need guidance for planning ahead.

Industry must be further organised and tabulated for making production quantities, and the increased capacity that will develop in the next two years must not be allowed to wither through lack of work.

Particular attention should be given to jigs, gauges, and tools, as well as to the maintenance of supplies of material and men.

Air raid precaution schemes should be developed: (a) To instruct personnel in protection; (b) to adopt in existing works, or embody in new factories those precautions that would help to maintain output.

PROTECTIVE METAL COATINGS BY THE WIRE SPRAYING PROCESS.

Paper presented to the Institution, Southern Section, by Major H. J. Williams.

GENTLEMEN, I do not propose describing the pistol and its operation at the outset, as I shall have an opportunity of doing so later when we show you the film.

To state the truth, going back to the basic invention of the tool, or what is more generally known as the pistol—metal spraying in its inception is probably as old as welding. In practice, however, it is only since the war that a reliable tool was produced, and the process developed.

If by welding we mean the fusion and alloying of metals up to 3000°F. and by metal spraying, the meaning to be the commercial deposition of molten metals for practical purposes, putting aside experimental and laboratory claims, I feel that it will be simpler for you to follow in many respects what I have to say to-night.

Welding in the meantime has advanced to such an extent that it is not only used in practically every industry, but has become a major industry in itself.

Metal spraying has had similar potential possibilities and in a field even wider than welding, but through mismanagement in its pioneering stages, has not succeeded in its commercial importance as compared to welding.

This has called for criticism, and metal spraying enthusiasts have not always been able to stand up in defence on account of the rather hidden history of its rather tardy development.

I feel, however, that I can safely state that many processes adopted in the British industry, of foreign origin and manufacture, have never shown real speed in their progress until the majority of the basic tools and materials necessary have been manufactured in this country.

This has been the situation in this country of metal spraying, as until three years ago the pistol was manufactured in Germany, and through that factor was suffered many disadvantages.

In this brief time, and which dates from the taking over and handling of the process by the company, there has been more

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Southampton, November 18, 1936.

business done, more serious interest created, and new and successful applications developed than for a great number of years.

Many excellent papers and articles on the subject of metal spraying have been at the disposal of the engineering and industrial community, and to-night I am departing from the orthodox by not going too deeply into the academics of the process, and intend concentrating more on its recent developments and general applications.

It should be noted, however, since the complete expiry death of the Master Patents surrounding the pistol itself in 1934, that while some of the metal spraying pistols abroad have a general similarity, decided improvements have been developed in this country, but I will be dealing more fully with the matter when we come to the film.

To make the difference comparative in operation—welding as to metal spraying—welding has but two variables to contend with : metal spraying has four—oxygen, acetylene (and/or hydrogen or cool gas), air, and wire feed, all entering one nozzle. It is therefore evident that a metal spraying gun is more difficult in its design and construction than a welding or cutting torch, and therefore the efficiency and development of the process has been far more dependent upon the efficiency of the gun.

It may be asked why from the outset of these preliminary observations I am introducing welding in what might be considered a confusion with metal spraying, but it is only because the extensive developments that have taken place, in particular these last two or three years, in America especially, in the reclaiming of worn parts by the building up of various steels, and in some cases nickel, by metal spraying, that I feel many in the welding industry will be adopting this process, not only because of its parallel applications, but in view of the fact that constantly they will be found to complement each other.

I wish, however, to state emphatically, that the line between metal spraying and welding is most definite, and that metal spraying could never infringe or displace present oxy-acetylene or electric welding applications.

Personally, I know little of welding, but I am authoritatively informed that a welder's training dictates several firm rules—a minimum of oxidation, and a maximum of fusion, to obtain the highest degree of tensile strength. This major objective overshadows the fact that the area welded acquires a very high temperature while the adjacent areas are at normal temperatures. I am also told that years ago this was a serious limitation, but methods were devised to neutralise many of the unsatisfactory results.

If metal spraying used a fusion bond, its field would be materially reduced.

It is not necessary or desirable to increase the temperature of an object being sprayed over 100° above normal, and therein lies a distinction which clearly separates the field of the two processes.

Anyone first viewing the spraying of steel, especially a welder, is usually shocked, if not staggered, by the apparent waste and oxidation in what in its first appearance is a "firework" method.

Consideration must be given to the length of time the metal is molten, as well as other factors.

Molten metal spray particles travel at speeds said to approximate that of shot gun nozzle velocities. The metal is molten less than one-hundredth of a second, or about one-thousandth as long as with welding.

Oxide inclusions, though greater than in welded metal, are not of the greatest importance, since the tensile strength is not the most important requisite.

Spray losses are largely due to failure of adhesion of a portion of the molten particles, but with surfaces properly prepared, deposits keep spray losses well within practical and economical limits, and with steel, for example, the losses need not exceed 10%.

Zinc, aluminium, and stainless steel, are some of the best spray metals to deposit, and which retain almost fully their original corrosive resisting characteristics.

A striking irregularity in metal spraying is the fact that pure molybdenum, with a melting point over 4000°F., can be easily sprayed, with oxy-acetylene, but, I understand, cannot yet be welded by oxy-acetylene methods.

The industries have adopted welding so thoroughly, and successful welding is so reliant on a fusion bond, that engineers sometimes forget that there are many other bonds that are fully adequate for their respective purposes and which are available by metal spraying.

Through the fact that metal sprayed deposits are propelled at a high velocity of air, they cause no warpage, no distortion, or heat strains, but it is also true that the deposited metal has only a fraction of the tensile strength and ductility of welded metal.

Sprayed metal does, however, have the ability to withstand all duty for which it is intended, and through the selection of metal which can be deposited, it is possible to provide a wearing surface infinitely superior to the original bearing surface.

As all depositions are relatively thin, there is therefore little reduction in strength of the part.

On the other hand, the granular structure of the sprayed metal, compared with the original metal or with welded metal, provides means for better lubrication.

It must be borne in mind that sprayed metal is cast metal, and can be turned or ground depending upon the character and hardness of the metal applied.

I am led to understand that the building up of customary worn areas on shafts has often been a difficult application by welding. The average wear even on a large shaft probably never exceeds $\frac{1}{8}$ in. on the diameter, and whatever welding method is used, a full $\frac{1}{8}$ in. to $\frac{1}{4}$ in. deposit on the side is necessary when repairing.

A sprayed metal deposit only requires about $^{1}/_{64}$ in. over the finished size, to grind down to size. Therefore about half the amount of metal need be deposited, with considerably less machining and grinding.

While it may be considered that metal spraying is far more economical and satisfactory for this particular type of work, yet welding may be considered superior for small area heavy-deposit machine part applications.

Since fusion of a sprayed metal with the base metal is not necessary, it is apparent that any metal may be applied to any other metal, and the restrictions relative to alloying in welding need not be observed.

A cast-iron piston may be built up with aluminium ; a bronze shaft with monel ; a low carbon steel plunger with stainless steel, or the reverse, or, as far as the process is concerned, with *any* metal available in wire form.

If each keeps to its definite field of application, it should never happen that differences of opinion could arise between metal spraying and welding. Welding is universally used, and the fact that it is available in most plants, has perhaps never given consideration that in some cases other methods might have served better.

I am using this opportunity for all welders to give their serious consideration to a large field that is open to them, and which would appear to be not so available with the accepted methods of welding —the building up of worn areas on shafts, or other circumferential worn areas—primarily because of warpage, heat strain, and other troublesome features.

I feel that the technique in the education of a welder will make him appreciate what is available by metal spraying, and the future is not distant when a pistol will be a profitable and recognised adjunct in most welders' shops.

I will mention a few concrete cases that are becoming constant practice, not only in this country, but in America and the Continent :—

(1) Cracked cylinder water jackets.
(2) Aluminium crankcases.
(3) Building up of crankshaft journals.
(4) Stub axle pins.
(5) Brake arms.
(6) Aluminium or cast iron pistons.
(7) Ball race surfaces and housings.
(8) Filling of porous welds.
(9) Higher carbon steels can be used in spraying than in welding, because it has been found that 20 to 40% of the carbon content is lost in spraying.
(10) An instance of the combination of welding and metal spraying : A low stage compressor piston of which the narrow ring sections were broken, and built up by welding (tensile strength here being the important factor) the diameter was then increased with stainless steel.
(11) One of the principal railroads in America have for a considerable period been having their monel metal pump rods and sleeves, which are used for feed water heaters on most locomotives, built up when worn, by spraying—*no other* method having been found satisfactory.

General Method of Building up Sprayed Metal Coatings.

(1) Building up is the expression used to describe the deposition of metal on shafts, journals, pistons, and similar machine parts by means of the metal spraying process. The expression also implies restoration to size of worn shafts and journals.
(2) There has been considerable research both in this country and abroad upon the question of wear-resisting properties of the deposit and also the strength of adhesion between the deposited metal and the base. Tests and experiments carried out show that the strength of adhesion obtained is very high ; for example, it takes some 20 to 25 tons direct pull to remove a collar of sprayed metal from a shaft, the collar being 1 in. long and the shaft 1 in. diameter, the collar having a thickness of some $\frac{1}{4}$ in. In this case the collar did not part from the shaft cleanly, but parts of the shaft and the sprayed metal were removed.
(3) For this aspect of metal spraying the same care and attention must be given to the preparation of the base metal as is given to the preparation of other bases for metal spraying. The technique differs in so far as the sand blasting operation is dispensed with, and the preparation of the base is carried out by machining in a lathe. This is done as follows :—
The shaft should first be machined under size along the section to which the deposit is to be applied. The under-size section should be $^1/_{32}$ in. on the diameter per 1 in. of shaft diameter. In other words, a 1 in. shaft should be $^1/_{32}$ in. undersize on the diameter

and a 4 in. shaft about $\frac{1}{8}$ in. under-size. It must be borne in mind, however, that this is only a general rule and the service to which the shaft is subjected will influence the thickness of the coating.

After machining under-size the shaft should again be machined with a " V " pointed tool mounted to attack the work below the centre line and a series of rings machined on a shaft like a machine screw thread, 20 to 30 cuts per inch. In this last machining operation the tool should be allowed to chatter and tear the surface to be coated.

The under-sizing and screw cutting can be combined in one operation, if desired, as it is only necessary that the under-size dimension be taken from the tops of the threads.

The machining must be done dry and no oil used and the surface kept clean after machining, after which the coating can be applied. It is desirable to apply the coating as soon as possible after the machining operation is complete to prevent oxidation of the freshly-machined surface.

The method described above is particularly applicable to shafts of low and medium tensile material. The technique differs slightly when high tensile heat-treated material is to be coated. In this case two methods are often used. One is to machine the surface with a Tungsten carbide tool, where the hardness of the surface is such that this may be accomplished, and the second method, although not specifically recommended, is to anneal the article, machine it as described above, re-harden it, and then to sandblast the surface to be coated. The application of the deposit is carried out as follows :—

The article to be coated is mounted in a lathe and rotated. The metal spraying pistol is attached to the tool post of the machine and is moved by the saddle mechanism. The speed of rotation of the article varies with its diameter, that is to say, a shaft of small diameter, one inch is rotated at a speed of approximately 90 revolutions per minute. On the other hand a 4 in. shaft is rotated at the speed of 40 revolutions per minute. This gives some idea of the peripheral speed. The metal spraying pistol is then put in operation in the usual manner and the spray directed upon the article to impinge upon the surface above the centre line. By this means the surface to be coated and the spray particles are moving in opposite directions, and the particles are therefore impacted with greater force. The lathe saddle and pistol is moved at such a speed to ensure the application of the maximum thickness of deposit per pass. Extreme caution must be exercised to prevent the article from becoming overheated. The temperature should not be allowed to exceed 250°C. at any time during the operation. The tail of the flame from the nozzle should be at least 1 in. from the surface being coated. The shaft should be built up .010 in. per inch of diameter

over the finished size and the 1 in. shaft will therefore carry a deposit .010 in. above the finished dimension and a 4 in. shaft will carry a deposit .040 in. above the finished dimension. This is done to allow for finishing so that a fair surface can be obtained in this operation. Care should be exercised to obtain an even coating and when sufficient metal has been applied the pistol should be stopped and the shaft allowed to cool before further work is undertaken.

The materials used for depositing depend, of course, on the service conditions of the article. A shaft which has to carry a heavy load at high speed should have hard wear-resisting surface. This can be arranged by using a steel of high carbon content, say, of .75 carbon. The Brinell hardness arrived at with this steel is 250 and 350. In extreme cases, steel having carbon content as high as .80 or .90 may be used. On the other hand, if corrosion is present, as is the case with piston rods, pump rods, and similar apparatus, stainless steel is best, and nickel or nickel alloy may be used.

The finishing operation can be carried out either by grinding or machining and polishing. A hard deposit must of course be ground, and soft deposits may be machined with a sharp pointed tool and light cuts. The surface can then be polished by the usual means. The grinding operation can best be accomplished by using a Carborundum wheel Grit 401, Grade L, Bond 29.

Technique of Spraying for Building Metal.

Considerable care and technique is required when spraying is to be used for the building up of shafts, journals, pistons, etc. It should always be borne in mind that the important thing is regulation of the air pressure which carries out two operations in the metal spraying pistol. Firstly, it drives the compressed air turbine, which in turn propels the wire through the gas flame at the end of the nozzle. This wire then becomes molten and is driven from the nozzle by a further supply of compressed air on to the job. It will be seen then that if this wire speed varies, a greater or lesser amount of oxide will be produced in the resultant coat. This, as it will be quite clear, is detrimental to all deposits which have to stand mechanical stress. The wire speed should be so governed that no variation takes place while spraying.

Secondly, mixture of gases will influence not only the wire speed, but again the oxide content of the sprayed deposit. There are definite limits to which the gas pressure should be set; above or below this limit it will be found that the wire will not melt properly, and that an incorrect speed has to be set in order to obtain a fine spray. This is a very useful check in knowing whether the gas pressure is correct or not. Here again, the distance of the nozzle from the surface to be sprayed should be such that the tail of the flame from the nozzle is at least one inch from the surface. It will

be seen by this, that providing this distance is maintained through out deposition no varying content of oxide will result, for if the metal remains in the air surrounding it during its passage from the nozzle to the job for a longer period than necessary, undue oxidisation will result. It should be borne in mind that this distance cannot be decreased beyond a certain point, otherwise undue heating of the deposited metal on the job will result. This again will cause excessive oxide on the deposited surface besides which pent up stresses will occur in the deposited metal while cooling takes place.

THE ECONOMY OF PLANT REPLACEMENT

Informal Discusion, Luton, Bedford, and District Section, opened by H. C. Armitage, M.I.P.E., M.I.Mech.E.

MR. ARMITAGE: I want to emphasise that this is an informal meeting. At a meeting of this character there is no real paper, but one opens the subject, talks for a few minutes, and then others get up and talk a great deal more about it than the speaker does; therefore I hope you are not expecting a formal paper. I am going to give you a few remarks, that is all.

When thinking over what to say I looked at the title of the talk and saw it was "The Economy of Plant Replacement." I had it in mind previously that it was "Economics of Plant Replacement," and there is a great difference. Economy of Plant Replacement implies there is an actual economy in replacement of plant, but it remains to be seen, and it is a debatable point, whether it is always an economy to replace plant. Experts have argued about it from time to time, and when one looks up treatises it is always pleasant to say that Professor Somebody said this, or Doctor Someone confirmed that, but I could not find any authoritities, therefore my remarks have to be made on what I have come across during a few years' experience.

The people who talk about this subject are generally cost accountants and auditors. It is quite a regular thing in most works once a year for the auditors to ask us how much one ought to depreciate the plant and arguments are frequently long and sometimes heated. The subject is one of considerable importance because it figures largely in settling the amount of income tax. The Government have the view that if plant is depreciated heavily, it is naturally a way of evading declaration of profits and they watch closely. Therefore it has to be done in a scientific way or there is likely to be argument. The first cousin to plant replacement is depreciation, and one ought really to start talking about depreciation before plant replacement.

There was a lecture given recently before the production engineers and I noticed that it was full of formulæ for replacement. Now I

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do not know whether any of you have tried to work with such formulæ, but if you can, good luck to you. I should be glad if you would give me your experience.

There is, unfortunately, only one way of obtaining money for plant replacement, and that is the basis of all action as far as plant replacement is concerned. In one's early days of innocence the idea is that there is any amount of money in the world and it is only necessary to say your capital is £5,000,000, £10,000,000, or even £15,000,000, and the whole world will come along and give you money to invest in your concern, and you can have whatever capital extension you find necessary in order to buy and replace plant and machinery. This of course does not work out ; plant replacement has to be obtained purely from profits. If there is no profit then there is no plant replacement. A plant depreciation fund is generally opened for the purpose of replacing plant, and this depreciation fund is taken from the profits and replacements are purchased out of it. Since depreciation figures are given in balance sheets the question is always one of major policy.

Now consider the life of a machine or any part of the plant. If you examine books issued by machine tool makers you will find that they give the useful life, and the theoretical life, of the machine at about ten years, but in older books I think you will find that machines are given a life of anything from fifteen to twenty years, and other items ranging up to buildings, which are forty years. I think forty years may be taken as the maximum life that any machines ought to have.

Shortly after coming out of my time I changed my job and was thrown into an old established works with a household name. Looking round the plant I found that the bulk of the machines were anything from eighty to ninety years old, and quite a lot had been built by Sir Joseph Whitworth. Most of the teeth in the lathes consisted of pegs rather than teeth. That plant really wanted replacing !

However, there is a line of years somewhere beyond forty and something less than 100 at which you will find it necessary to replace your plant, in the hard school of practical profit making !

But if you are a general manager, interested in production, your main interest must be to have your plant up-to-date, and every time a new machine comes out you want to buy it and try it out. Generally speaking, the board of directors have got their eye mainly on profit. They also know that every machine you purchase is going to be so much less profit at the end of the year. If their remuneration depends on the profit declared, you will find they glance with very, very cold eyes on plant replacement.

The only provision in every company for plant replacement is the depreciation fund. This consists in writing so much each year

off every machine that you purchase. For example, on a machine costing £500, the general scale is anything from 7½ to 10%. If the purchase value of the machine is £500, it is 10% less or £450 at the end of the year. At the end of another year you knock off another 10%, generally that is 10% of the £450. Now if you carry that on, if you always take 10% off what is left, there is always a value attached to the machine. That is partly correct in practice, and you will find if you draw a curve, that it is always approaching zero but never gets there! A machine tool even if out of date is always at least of some value as scrap metal, and that is just about what the value stands at after you have taken twenty-five years on the "10% off the remainder" basis. Suppose you have a plant with a value of £100,000, and you wrote off 10% of your purchase value (I do not think anybody would let you do it; I suppose it would be nearer 5 or 7½%). That means at the end of the year you can knock off one-tenth of the £100,000, so your plant is supposed to have worn out £10,000 of its original value by the end of the year. That means you have got £10,000 in your depreciation fund to buy new machinery. If you have a turret lathe that is worn out, you are not forced to buy a turret lathe because a turret lathe is worn out. If you have £10,000 to spend on replacement of plant, and that £10,000 is spent on plant, then your plant is exactly at the same value as it was a year before, and so you would go on year after year—but all the time your plant would be getting bigger. If you did not depreciate your plant, is is quite obvious that at the end of twenty-five years there would not be much of the original plant left, or rather it would be there, but next to worthless, consequently, the company would no longer exist or it would be ineffective as a working unit.

This depreciation fund has got to come out of the money you charge for your goods. Depreciation is written off once a year, and as a practical person and as a production engineer you naturally want to spend this £10,000 on plant. Can you do it? I would be very, very, glad if you succeeded in getting the depreciation which is put in the balance sheet at the end of the year to spend on new plant. What generally happens, of course, is that depreciation is solemnly put into the balance sheet, but having got there year after year it may be used for all sorts of things. I have even known dividends to be paid out of depreciation! Instead of all this theory which is put forward by the accountants, you will find that what generally happens is that the board of directors decide what they can afford to write down for depreciation in your balance sheet. As for you getting much to spend on your plant, well, I do not fancy your chances! If you are very prosperous then the amount which is generally put by for plant replacement is generally what the income tax assessor will let you get away with, but unfortunately, is not always equal to what you get to spend. When you are talking

to the income tax assessor or the auditors then plant wears out at a terrific rate, you give them most convincing figures, and they allow you to depreciate your plant by that amount per annum, perhaps ! The next consideration is whether your company considers it politic to show a large profit or not, and also in some cases, again varied by the remuneration of the board, if it relies to any extent on the profits. Further, there is the general practice of your competitors. If your competitors are price-cutting and not making any depreciation on plant, then you have to do the same. This happened in the electrical industry just before the outbreak of the war. Then you must ask the accountants definitely to put this money into a fund, lock it up tight in a bank, and say that it shall never be used for anything else but plant purposes. I rather fancy that that action on their part will prevent unforeseen difficulties.

It has always been a source of interest to me to find out how American companies deal with plant depreciation. All American motor car firms are able to spend money on plant far more extravagantly than we do. If you go into an American motor works you will find the most up-to-date machines installed and I have yet to find how or where they get the money to do it with. They have much higher turnover, but I always fail to see how they make provision for plant replacement in the balance sheets. If you pick up any American papers interested in machine tools you will find they tell you that a machine is completely obsolete and has to be replaced in five years with all sorts of arguments why it should be necessary.

Let us now try to settle what is the reasonable life of a machine tool. I will talk from practical experience. I think that the minimum life of the average machine tool is at least ten years. It can last up to thirty or forty years, and if you run your plant properly I think you can manage to get thirty or forty years on most types of machines. Others you cannot make last ten years however hard you try. It generally happens that you start off with a brand new machine and can get good and accurate work, but at the end of four or five years, owing perhaps to the continual dropping of tools on the slides by the operator—apart from general wear—the accuracy of the machine is gone. Thus at the end of their four or five years it will need complete overhaul if you are going to put the accuracy back, and I am quite certain that if you thoroughly overhaul every part of a machine tool it will be as good as new, and in most cases even better than new. Again, that machine goes back into commission and once again starts on its operations, but this time it will not last five years, and if you get three years before it wants complete overhaul again you have done very well. Once again it goes back and you hope for another three years, but you do not get it. This time it needs complete overhaul after two

years, and once again it goes back. It has probably got slightly obsolete by now and does not show up well against the younger machines and the result is that it only lasts one year. At the end of that time its use as an accurate machine is entirely done!

On the other hand, let us assume that you have not been so assiduous or systematic in your overhauls of the machine, and have let it go. Then you will have started it off with an accurate operation, then a slightly less accurate operation, then again a slightly less accurate operation, then just a little skimming operation that has no accuracy about it, but just moving off metal. On that basis your machine, with running repairs, will last twenty years, or, with luck, thirty years—it all depends on whether a shop truck bumps into it or not! This, I may say, applies to a lot of machines, because the majority get their accuracy from the jigs and tools you put on them instead of from the machine itself. In most manufacturing machines, you merely use the machine for turning the job round, and put the work accuracy into the tool equipment and fixtures.

In a motor car works not more than 25% of the machines require extreme accuracy in their essential make-up. Turret lathes, grinding machines, and gear cutters have to be accurate, and they will represent about 25% of your machine tools.

Again, conditions in works and factories are vastly different so far as this question is concerned. If you are a machine tool maker it is obvious that you cannot use your machines in the slightly decrepit condition I have mentioned. You are forced to have accuracy in your machines, and, what is more, you have to put the highest skilled labour you can find on the most accurate machine tool you can find, because the more accuracy you put in machining, so you save in fitting. Therefore, in a machine tool works I should say it is most important that the machines should be accurate and carefully looked after. If you come to the ordinary factory you can look at the problem from the slightly different point of view already outlined.

Let us now see what reasons there would be for throwing out a machine and regarding its useful life as finished. If a machine is consistently breaking down and you cannot rely on it you have got to take some sort of action, and if it does this continually you have got to throw it out. The second reason, if you are persistently overloading. Third reason, if past repair. Fourth reason, obsolete type, probably owing to a completely new process. An example of this was the Heald oscillating cylinder grinder when honing was developed.

In deciding your replacement policy quite a number of things have to be considered. I am speaking again now of the factory. For example, the question of whether you should have a relatively

small number of absolutely first-class machines or whether you should have a much larger number of heavily depreciated machines with the same value total in both cases. This depends on whether you have the ability to organise your works or not. If you can regulate the flow of your material, time the arrival and departure of every batch of work to a schedule, if you can manage to do that and have first-class machinery which never breaks down, well, you can then probably afford to run your plant replacement on correct academic lines. It is up to you to decide whether this organisation functions, and whether it is not better and easier to have a larger number of machines and employ a smaller part of their time. I do not need to tell you that it is far easier to run a production shop with one machine for every operation without the necessity of pulling those machines down, than having one machine that will do the job at six times the speed, but which has to be changed over six times in the week. In the one case you could perhaps afford to have second-rate machines and keep them set up for one job. In the former case you have one first-class machine which you change over four or five times a week because it does its work very rapidly and you cannot afford to keep it unemployed. It is, I hope, clear from these remarks that you cannot lay down a fixed law for plant replacement on either basis, but the line will be actually somewhere between the two. Personally I should prefer to run a shop on second-hand plant and have a machine for each operation. Another factor is whether it is preferable to have a large number of machine tools and a small stock of work, or a large stock of work and a small number of machine tools. If you are going to have a machine changed over four, five, or six times in one week, it is obvious that the machine has to do a big batch of work before you change it over. Once again comes the comparison, and, however good your organisation you are bound to have a large stock of work as alternative to a large number of machine tools. If you had to decide which you would prefer, would you rather show a large work-stock in your balance sheet or a large number of machine tools? Note that you need not show a large number of machine tools, but you do have to show the large stock. Does this not indicate a preference, from the financial point of view, to have a large number of machine tools of not quite such a good standard as a large stock of work with a few machines of the most up-to-date type? I am hoping this will give rise to some discussion.

There is yet another point. Machine tool makers try to persuade you to buy new machine tools. They will tell you it is absolutely necessary and that it is high time this or that machine was thrown out. If you try and examine a little more closely whether it is going to pay you to throw that machine out or not, you will find

that it is difficult to show that you are going to save money by buying machine tools. If you are taking twenty-five minutes to do a certain job and a machine tool maker can put in a machine that will do the job in twelve minutes he will tell you you ought to throw the old one out. I know many cases where you would lose money in installing a new machine that would do the job in the shorter time. Your anxiety to purchase a new machine tool can run away with you—you want to buy a new machine tool, you like its novelty, all sorts of reasons influence you, and it takes a great deal of will-power not to do it. In nine times out of ten you lose money by buying new machinery.

When you put your new machine in, how many weeks does it take before that machine thoroughly gets down to its work? The machine tool maker will perhaps guarantee it to do the job in two minutes, and come along again after three or four weeks of frantic endeavour and offer 3½ minutes, tell you of all the money he is spending in sending his expert operators round, and will you let him off at 3½ minutes, and that is how it generally ends up. Explain that you bought " production " and insist on two minutes and you see that it is your fault entirely that the two minutes has not been attained.

I am trying to show all the way through my remarks the difference between what you should be able to do theoretically and what can be done as a practical proposition.

Another method of expressing the life of a machine, reputedly from America, is to measure the life of a machine in a term of working hours. When one visits America they tell you that they cannot tolerate any machine in the factory with a life of more than, say, 5,000 hours. When it reaches 5,000 hours it is thrown out and a new one purchased. Now that is fine, but can it be done? I should like to know if anyone has had any experience of the difficulty of collecting the 5,000 hours.

I notice, however, that there is a slight change of mind coming over our American friends on this subject. A symposium was drawn up recently and all works that were using machine tools were asked to give the number of machines they had and the age of each. It was found that between 65% to 70% of the machinery in American works was over ten years of age, and I think that compares favourably with us. I think this same level would apply in England.

MR. R. W. BEDFORD (Chairman): We have listened with interest to the discourse of Mr. Armitage, and the meeting is now open for discussion. If we all reply to the questions he has put, I think there is about one each, so we ought to have a very full discussion indeed.

MR. HARPER: I would like to say that Mr. Armitage has not

mentioned anything about the money he is going to save by putting in a new machine. I think the price you are going to pay on the machine should enter in greatly on the class of machine employed. The statement he made as to whether it was more economical to have five machines set up, one for each job, or one high-class machine which you break down five or six times a week, again depends on how you are going to pay the operator for working the machine. It means that you have five machines which are only working part of the week. That means you have got to pay more price per piece because it is a slower method, and in my mind it wants very careful consideration as to whether you are saving money by keeping five machines against one high-class machine. Also, there was one machine Mr. Armitage did not mention, that is the multi-tool machine which is working twenty-four hours a day, probably with 10 former tools, which, in my opinion and experience, wears out any machine. In my experience I have found that if you get three years' life out of one of these machines you are doing remarkably well.

MR. HAZLETON : I do not suppose it would be possible to get anything worth while in the way of statistics as to what is done with the money that is laid aside each year for depreciation, or how it is used. Mr. Armitage told us that the theory is that it should be put aside for replacement purposes. Can he give us any rough idea how far that is actually done ? Again, would it be desirable, if it could be managed, that there should be a law to provide that money set aside for depreciation must be used for that specific purpose ? If it is left to the whim of directors they can do as they please and the national interest may suffer very greatly in efficiency. I suggest that such figures as are put in the balance sheet for depreciation should be spent for that specific purpose. Perhaps Mr. Armitage would say whether he thinks this is a question in which the Institution could interest itself, in association with chartered and cost accountants.

CHAIRMAN : Mr. Armitage has made several polite remarks on machine tool makers and their agents and I am quite sure we should get some interesting reply if there are any machine tool manufacturers' representatives here present.

MR. BEST : Some years ago a member of Mr. Armitage's firm—Mr. Perry Keen—speaking in Birmingham, conveyed the impression that they were given so much money to turn out a motor car and they have that money to build up the car by several different operations. They found certain shops could turn over the end of the crankshaft at, say, 3d., whereas their cost was 3½d., therefore they would have a machine which would do it at 3d. It is the smaller companies who have the greater difficulties, as there is less money available than with, say, the Austin Company,

but, like the man with the small car, he gets more experience out of it than the man with the large car, but could Mr. Armitage let us know how far these cut limits of, say, ½d., come in, in, say, a works in Birmingham ?

MR. HOLMAN : Apparently you cannot rely upon the Income-Tax schedule, and I should like to ask is it not possible to go on the insurance value of the plant, as obviously the insurance company would only allow you so much, and I should think that would be one way of determining the value of your plant. Another thing, surely the life of a machine must depend on the various ways in which various firms run their machines ? Obviously machines in a large works running full time at high speed must wear out quicker than in a small engineering firm which may possibly run their machines at low speed. Again, taking those large firms which have single-purpose machines due to the layout of operations, these machines may only run a normal percentage of factory hours, and a machine running, say, two hours a day would obviously last much longer than a machine running all day long.

MR. ARMITAGE : Regarding Mr. Harper's remarks, I have purposely, in all my remarks, slightly stretched them in order to give them a little more colour than they might otherwise have had. When I spoke of five machines being replaced by one perhaps that is a slight exaggeration, but let us talk of five machines against one. Let them stand in your books at, say, £50 each, as it is quite easy to get them down to £50. Your brand new machine will probably cost you £1,500. Calculating your machines, five at £50 each, equals £250. Take depreciation on £250 at 10% per year, £25. Take your brand new £1,500 machine, on the same basis £150 goes off for a start. Deduct again your floor-space—if you have not got plenty of floor-space it is not possible to have several of the older type machines. I do not know whether any of you put out orders for small parts, particularly automatics, but if you look round some of the plants in Birmingham you will find they have a number of the old Cleveland Automatics that were doing good service in the war. Each one is set up to do one job ; it turns it out very slowly, perhaps, but it is doing its job. Now I find when we in a large works come to the same job we have a 4- or 6-spindle Gridley, and however hard we tried we could not possibly get down to the costs of those old Clevelands. We have a group of those Clevelands which are still going ahead and still justify the rather extravagant floor-space they take.

You must not allow an expensive machine to be idle ; if you calculate the cost of a £1,500 machine being idle you will get a shock. The machine costs you 6s. to 7s. per hour, but for the operator, at most, 2s. 6d. per hour. Payment of the operator is comparatively negligible to the hourly process rate of the machine,

and it is far more important to have the machine working than the man. One thing happens in a workshop, a man is never allowed to be idle, but if you examine the plant you will find that at least 25% of the machines are not actually producing. I am sure of being conservative in saying 75% are at work when 99% of the men are at work.

In regard to the three years life Mr. Harper spoke about; if you have a multi-tool machine with form tools you will be asking for expense. When working on cast iron the slides wear out rapidly. I remember putting in a 6-spindle machine for a certain job. It did the job most efficiently but was worn out in two years, as the dust from the cast iron got into the slides and it was little more than old scrap in that time.

Mr. Hazleton spoke about the funding of depreciation. There are dozens of things to consider. Suppose you try to arrive at the value of this or that machine to decide if it should be replaced. Here are the points to be considered: (1) What the machine cost new; (2) Age; (3) Type, that is, how many generations of machines have succeeded that particular type—there may have been three machines brought out which follow that particular machine; (4) The Book Value; (5) Market Value; (6) What it would cost to buy a more up-to-date machine; (7) Cost of complete overhaul; (8) How many overhauls it has had; (9) What you would get for the machine if you sold it; (10) Possible production economy; (11) Possible use of the old machine on a minor operation. There is a rough and ready rule to decide whether a machine wants replacing or not and which I frequently use in preliminary investigation. If it costs more to overhaul a machine than its book value, then it is time to replace it by a new one, but if the cost of overhaul is not anywhere near its book value, you can make out a case for one more overhaul.

Mr. Hazleton suggested that we ought to try and approach chartered and cost accountants to get an Act of Parliament on depreciation. I think it would be a good thing to get an Act of Parliament that would force all companies to spend their depreciation fund on new machinery. Incidentally, it would do more to stop price-cutting than anything that has yet been started, but if a firm makes a declaration of depreciation for income-tax purposes they should be forced to spend that money on new machinery. I think, however, that this would cause considerable consternation.

Regarding the question as to how companies value their plant and machinery. If they are going to make a new issue of shares they get hold of a valuer and ask him to go round the works and make a valuation. He goes round, says "How many years old is that" and "I think we can put that in at £400," and so on. Thus the plant is valued, and you get a certificate from him which is

duly put forward to the world in order to get money invested in their company. Of course, the valuer, being paid by them, is not influenced in their favour to the slightest degree!

Now that question of American companies replacing every five years. I have tried to indicate already the slight contradiction, but American papers give you the idea that machines are thrown out rapidly in the United States, but they contradict themselves in other places. Actually, on the whole, I do not think they are much better at replacing machines than we are in England. The small concerns in America use old plant just as much as the small concerns in England.

Dealing with the question by Mr. Best, Mr. Armitage mentioned that Mr. Perry Keen was an esteemed colleague of his, but that whereas he himself had coloured his remarks in one extreme, Mr. Keen had perhaps coloured his remarks in the other, and remarked that if one knew the real costs—not the costs as put forward, but costs as they actually were—everybody might get some surprises. If you are up against output in order to produce 500 of a certain article in forty-seven hours, have got a machine which will only produce 400 and a group of others able to produce 500, it is obviously worth almost anything to get the machine which will enable you to produce the full 500.

Mr. Holman mentioned assessment for income-tax and fire insurance. These must of necessity be different figures, as the latter should cover you handsomely. It is disastrous to be economical over insurances. If you had a £500 machine you would probably insure it for £600 or £700 so that you could not be accused of under insurance. If you were under-insured it would be difficult to get sufficient insurance to pay for the replacement value of a machine.

Mr. Harper: I would like to carry on the discussion where you left off about the £1,500 machine. Basing on 10% depreciation. about £3 per week, on a forty-eight hour week this works out at roughly ¼d. per minute not taking into consideration the depreciation on the old machines, as obviously it would bring it down lower if you deduct the depreciation of the old machines from the £1,500 machine. Working from ¼d. per minute, which is capital outlay, and with, say, an average oncost of roughly 200%, you have got to save possibly $^{1}/_{10}$ of a penny per minute to make that machine pay. I still maintain that it is a paying proposition to put in a new machine as against having several old ones.

A Visitor: I think what Mr. Harper is getting at is this: you do not always put in an expensive up-to-date machine when you replace old machines. For instance, I think you could get a good multi-cut turret lathe at £750, not £1,500, and by using £750 on special tool boxes for a large number of jobs, that would easily

wipe out five fairly good combination lathes, always assuming those jobs are of suitable diameters.

MR. ARMITAGE : I certainly agree with you, but I am speaking more where you get a job done particularly on those old machines ; where perhaps one man is working five or six of them. Generally speaking, the older the machine the more skilled labour you have got to put on it in order to get anything out of it at all. The newer the machine the more it should be able to be worked by a low grade of skill, but low grade of skill has to be counterbalanced by an enormous amount of other classes of work. For instance, we are persuaded to make milling cutters of Widia on the ground that it will stand up to a higher speed on milling than an ordinary high-speed steel milling cutter, but you pay £45 for a Widia cutter as against £5 for a high-speed steel cutter. If you come across a hard spot in a casting and you are running your Widia cutter at six times the speed, the Widia cutter gives out just the same as the high-speed cutter. Calculate the length of time that it is going to take to grind that Widia cutter, you will find it will take five or six times as long as the amount of time used by the running of a high-speed cutter at the slower speed and feed. With Widia you have got to be careful how and when you apply it. It is exactly the same thing with super-machine tools. They have gadgets for all sorts of things, but if anything goes wrong you have got to get an expert to tell you how to repair it and all that time the machine is standing idle. It is the case of the plumber and his mate, the expert has to get a replacement part, but all this does not appear on the cost. It ought to do ; it is actual cost, but is rarely calculated. Mr. Harper has worked out on percentage of charges against production. That is incorrect.

A VISITOR : Nevertheless, Mr. Armitage, you have got to agree that if someone had not taken a chance with a motor car, that motor cars would not be very far advanced.

MR. ARMITAGE : Now you are talking about something rather different. Under the excellent schemes now at work, you can have a new car every year and it can be proved quite easily that you lose if you do not do this. The same thing ought, I think, to apply to machine tools. The life of a motor-car is something like four to five years before it gives you any real amount of trouble, but it really pays you to trade in and buy a new one after twelve months. If machine tool makers traded in machine tools in the same manner as the motor car industry, then I think manufacturers would have a very good proposition. You pay £500 for a motor car, run it down the street, come back, and it is only worth £400. The curve of actual market depreciation on a machine the same as the motor car, in other words, for the first year depreciation is enormous. Try and sell a machine tool that is a year old ; if you

get a quarter of what you paid for it you will be lucky. But buying a second-hand machine one year old will cost almost as much as a new one.

MR. JOHNSON: You remarked about Widia. This is an actual experience of mine in a small firm. They had a cast iron casting in the lathe that had a hard spot in it. The works engineer had had a small sample of Widia given him. They put it on the lathe and it ran through the casting just like cheese in no time. The firm put through an order for Widia tips for machine tools for a small bay of 10 to 15 lathes, and when the price came through it amounted to £760.

A VISITOR: Suppose with a small factory you have got one new machine replacing five old machines, you have got more floor space available, which is obviously an asset if you are a small firm, also if you have five machines running with electric motors you have less power consumption with one machine instead of five.

MR. ARMITAGE: It is only an asset if you can use the space. Frankly, I think the modern machine tool has run slightly past itself. Whereas the machine tool maker used to come along a few years ago and charge £400 to £500 for a machine, I find if you get anyone to quote you less than £1,200 to-day you are very fortunate. Machines you used to get for £300 to £400 to-day cost you £1,000. It is somewhat of a paradox if you have two machines put in front of you, one of which costs £1,800 but is a reliable solid first-class machine tool in every way that will work straight away, and are also offered an inferior machine at half the price it will pay you to buy the £1,800 machine straight away. I only know one company in the world which can make a complicated machine tool work straight away. This may appear contradictory to previous remarks, but the reason why machine tools have gone up to such high prices is that we ask too much of the machine. We put all the risks on the machine tool maker and, as a result, he charges cover for it—whether you require it or not.

A MEMBER OF THE AUDIENCE stated that he considered quite a good case could be made out for the new machine, as in a lot of works everyone was in a groove, but if you put in a new machine it created a different atmosphere and often resulted in the older machines being reconditioned to keep them in line with the new. His firm had had some very successful runs on old machines that had been reconditioned, and they had been able to produce certain modifications in old machines which had been very successful, but it was a matter of consideration before you decide to put in a new machine. Continuing, he mentioned his firm put in three new drilling machines which did the work of six old machines and which therefore must prove economy, but in his opinion the nature

of the work and the quantity must come into consideration before you decide.

MR. ARMITAGE asked whether anyone found that a reconditioned machine lasted as long before it wanted overhauling again as it did when it was new. Those that had been reconditioned during the depression had lasted well up to the present. Many of the machines were fifteen to twenty years old and they would last another three years quite well.

Replying to a remark as to the desirability of working a machine well inside its capacity, Mr. Armitage said that nothing taxed a machine more than running it at 100% load or capacity. He instanced a 3 in. forging machine which, if it had 3 in. work consistently, would rapidly break down, but a 5 in. machine working on a 3 in. bar would last almost indefinitely.

MR. SPENCER: I should like to ask whether the cost for repairs comes out of the depreciation fund, also if money set aside for depreciation is not all spent on depreciation, there must be a serious leakage in the balancing of the accounts?

MR. ARMITAGE: I quite agree that large repairs should come out of the depreciation fund; that is perfectly right because that is bringing the machine back to its original condition. The ideal would be to spend the money on the machine itself. Take a £500 machine: depreciation at 10% would be £50, then theoretically this £50 should be spent on the machine. If that were done every year, the machine would always be in brand new condition. In practice you cannot spare the machine from production to do this, and overhauls ought not to be necessary except at intervals of three to five years. Running repairs should come out of a fixed maintenance charge.

A MEMBER OF THE AUDIENCE, referring to a previous statement, asked whether there had been cases of depreciation being necessary before profits were made and said he understood at one time the Austin Company was spending a lot of money on plant which could not have come out of profits, because there were no profits.

MR. ARMITAGE: Plant purchase reduces immediate profits. At the end of the war all works had grossly inflated, and many of them had doubled or even trebled their size. They all bought worn-out plant from the Government at apparently remunerative prices and they set out to spend a lot of money in changing works over for peace-time production. All of a sudden the bottom fell out of the market, between 1920 and 1922, whereas it did not hit America until about 1929. The result was that all the so-called war-time wealth had gone and everyone had got to get down to earth again. They existed on their fat, and tried to develop other markets by using up their accumulations. There was no depreciation put aside during those years. A company that is not making profits cannot

put money aside for depreciation ; they could not afford to, because the less money they put in the depreciation fund the less loss they would show. Theoretically money should be put in the depreciation fund to build solidly for the future, but unfortunately things often have to be dealt with in the present.

MR. HARPER asked whether the amount of money spent on conditioning a machine goes on to the machine after it had been reconditioned, and Mr. Armitage replied in the affirmative.

A MEMBER OF THE AUDIENCE remarked, in reference to reconditioning machines, if the age of a machine was roughly ten years, if it was depreciated 10% per annum, the reconditioning would be very expensive.

MR. ARMITAGE, replying, said fortunately there are so many operations that do not always want the machine to be right up in tip-top condition. One should endeavour to keep a reserve stock of machine tools, then when a change of design is required, repaired machines can be installed at the week-end, thus taking the old ones out and putting freshened ones in. Those that come out should go to the machine repair shop, or, if finished with, to the junk heap or sale yard.

A MEMBER OF THE AUDIENCE : I should like to ask what depreciation is taken where plant is running twenty-four hours ?

MR. ARMITAGE : Theoretically, if a plant is working twenty-four hours a day it ought to wear out twice as quickly, therefore all I have told you is divided by two. When I spoke of ten years it brings it to five years if working day and night.

A MEMBER OF THE AUDIENCE remarked that he considered 25% of repairs could be saved by keeping a machine to the same operator.

MR. ARMITAGE : Nothing does a machine more damage than two or three operators. No one of them is directly responsible. It is always the other man.

THE CHAIRMAN : I have listened very attentively to Mr. Armitage's talk and the general impression I got was a rather discouraging view of purchasing new and expensive machines, and I began to feel rather impressed by his arguments for the reconditioned machine. I think he has led us along the line of thought that you have got to take both sides of the question into account, and although in my own mind I am convinced that one of the reasons why the high-priced modern machine tool has developed has been caused by the necessity of working to accurate limits which the old machine has not produced, I do not think he has developed that line of thought to the extent he might have done. You could not get any modern motor car factory to produce a car at the price on the market to-day if they had machines twenty years old.

MR. AULT proposed a vote of thanks to Mr. Armitage and this was cordially adopted.